From the EPA/NPS network, computations for 19 locations over 6 seasons from summer 1978 through fall 1979 indicate an overall geometric mean standard visual range of 165 km. If we assume $\chi_{fp} = 3\mu gm^{-3}$ over the test region (to be described in Chapter 2B) and time period, then use of (8) leads to $k = 4.6 \cdot 10^{-3} (\mu gm^{-3})^{-1}$. This agrees within 10% to the value found by Macias and Husar (1976).

Using airport observations in the southwest, NASN (National Air Sampling Network) data, and emissions data, the rate of change of attenuation coefficient with SO_2 emissions has been studied by Marians and Trijonis (1979). We will define such a change by the coefficient b:

$$b = d\alpha/dE_{SO_2}.$$

Because we assume that fine particulate dominates the variation of attenuation coefficient, then

$$d\alpha \simeq d\alpha_{fp}, \text{ so } b \simeq \frac{d\alpha_{fp}}{dE_{SO_2}}.$$

Solving for the change in fine particulate concentration as a function of changing SO_2 emissions,

$$\frac{d\chi_{fp}}{\% \; O_2} = \frac{d\alpha_{fp}}{\% \; O_2} \cdot \frac{d\chi_{fp}}{d\alpha_{fp}} = b/k.$$

Marions and Trijonis (1979) found

$$\frac{d\alpha_{fp}}{dE_{SO_2}} \sim 2 \cdot 10^{-3} km^{-1} \text{ (1000 tons } SO_2 \text{ per day)}^{-1}.$$

If we let $k = 5 \cdot 10^{-3} \; km^{-1} (\mu gm^{-3})^{-1}$, then $\frac{d\chi_{fp}}{dE_{SO_2}} = 0.4 \; \mu gm^{-3} (1000 tpd \; SO_2)^{-1}$.

This rough relationship is used here with projected changes in the SO_2 emission inventory affecting the region to estimate the resulting change in fine particulate concentration. It is a rough relationship because the regression analysis used to produce the coefficient does not take careful account of different categories of sources, the various mechanisms by which these sources lead to ambient fine particulate concentrations, and the resulting attenuation coefficient.

We can derive an estimate of the fine particulate concentration prevailing in a picture. Combining (4) and (5), we get

$$\chi_{fp} = \frac{1}{k}\left(\frac{1}{r}\ln\frac{C_o}{C_r} - \bar{\alpha}_R\right). \qquad (9)$$

Equation (9) is used to compute the fine particulate concentration we expect to be associated with each photograph used in the survey, assuming the particulate concentration is uniform throughout the vista.

c. Emission Scenarios

Now we want to develop scenarios of future anthropogenic effects on visibility in a test region defined as southern Utah, southwestern Colorado, northern Arizona and.northwestern New Mexico (see Figure 4). One of the important driving forces will be the increase in energy related activities, including coal mining, coal combustion to generate electricity, coal conversion to liquid and gaseous fuels and the diverse activities of new people moving into the region.

All these activities create pollutant gases and particulate, some emitted in the region and some transported into the region from similar activities upwind. Fully recognizing the possibility that other sources may be more important, we will arbitrarily simplify this complex set of sources and pollutants by focusing on only coal-fired power plants, the SO_2 they emit and the resulting sulfate fine particulate that affects visibility. This approach seems justified in this specific test region because the proposals for coal-fired power plants there far outweigh the proposals for other major sources of air pollution in the same region (Walther and Comarow, 1979).

The scenarios are developed for sources that are proposed to be constructed by 1990-1995, because information from various energy projections is available only to this future time period.

Scenario O

There may be no appreciable change in SO_2 emissions (EPA, 1979; Mitre Corp., 1979) because the increase in power plant emissions may be offset by the decrease in smelter emissions. If we assume natural SO_2 emissions also do not change, then we are led to a projection of no change in sulfate fine particulate. If we also assume that sulfate dominates fine particulate, then we project no change in ambient fine particulate concentration, hence no change in the attenuation coefficient of fine particulate. There would be no change in apparent contrast of any target in the test region. This ‘no change’ scenario provides no basis for asking people about the economic value of a regional change in visibility related to energy development.

Scenario 1

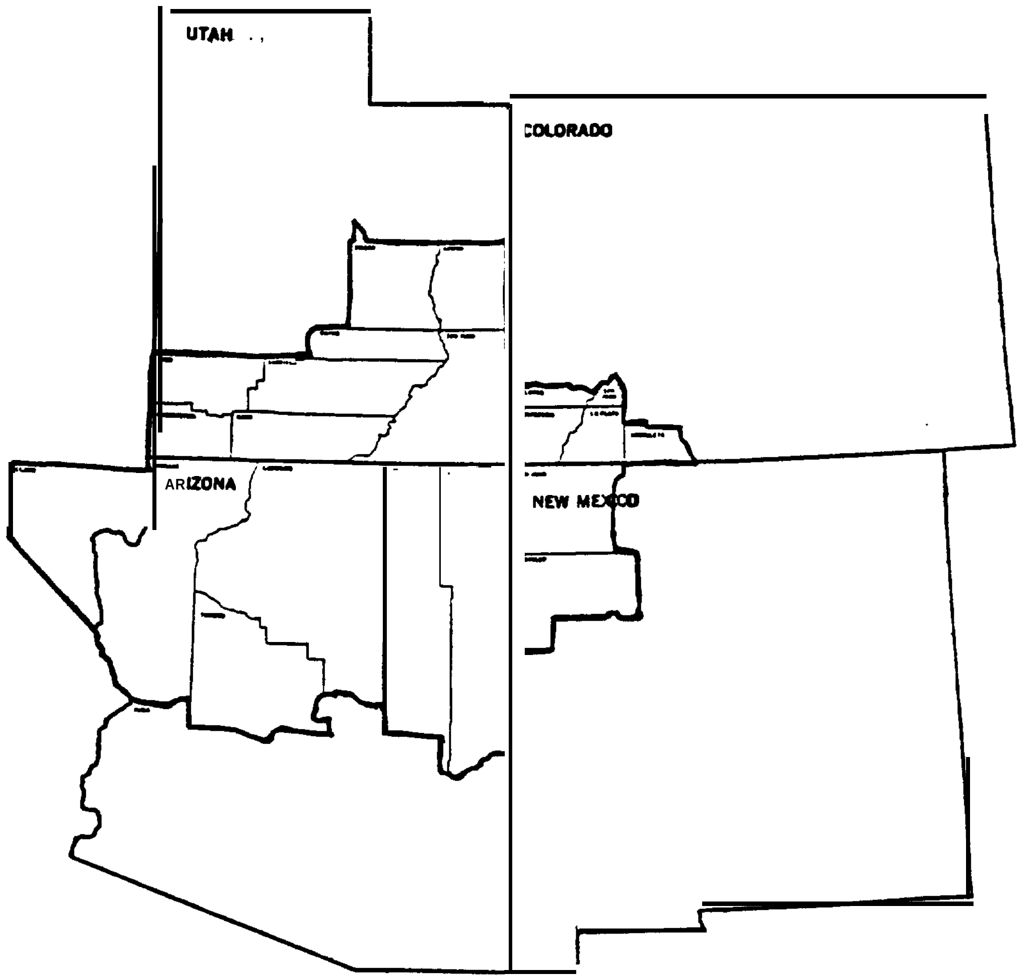
In order to develop a scenario based on a definite change in em'issions, the the smelter emissions contributing to the test region are assumed to remain constant.

In the test region the current major sources of SO_2 are listed in Table 4. All these sources are coal-fired power plants.

The size is given as a range where various sources of information differ.

Figure 4

Test Region



State	County	State	County
Arizona	Apache	New Mexico	San Juan
	Coconino		Rio Arriba
	Mohave		McKinley
	Navajo		
	Yovapai	Utah	San Juan
			Kane
Colorado	Archuleta		Washington
	Dolores		Iron
	La Plata		Garfield
	Montezuma		Wayne
	San Juan		Emery
			Grand

Table 4

Current Major SO_2 Emissions In Test Region

Name	Location	Unit	Power (mw)	Control (%)	Sulfur Dioxide Level lb SO_2 / 10^6 BTU	Emissions Rate (tons per day) Controlled	Emissions Rate (tons per day) Uncontrolled
Cholla	Joseph City, AZ	1 2	110-115 250-270	>90[1] >90[1]		7[2]-13[3] 7-13	22-40 22-40
Four Corners[3]	Kirtland, NM	1 2 3 4 5	190 190 245 778 778	65 65 0 0 0		8.5-20.5 8.5-20.5 10-24 90-160 90-160	35 35 40 160 160
Hunter (Emery)	Castle Dale, UT	1 2	400(N)-430(G) 400(N)-430(G)	80 80		7 35	26 26
Huntington[2]	Huntington, UT	1 2	400 415	80 80		21.5 21.5	26 26
Mohave	Bullhead City, AZ	1 2	820 820	0 0		40,46[3],50[2],64 40,46, 50,64	40-64 40-64
Navajo	Page, AZ	1 2 3	770 770 770	0 0 0	.5216 .5216 .5216	46.7[3],55.7[4],81.3 46.7[3],55.7[4],81.3 46.73,55.7 ,81.3	46.7-81.3 46.7-81.3 46.7-81.3
Coronado	St. Johns, AZ	1	350(N)-395(G)	66*	.816	38	113
Reid Gardner[5]	Moapa, NV	1 2 3	110-130 110-130 110-130	80 80 80		16.7 16.7 16.7	83.3 83.3 83.3
San Juan[3]	Fruitland, NM	1 2 3	360 350 500	67 67.5 67	.55 .53 .55	22 21 35	67 65 106
TOTALS		23 units				692-1074	1398-1587

N = net rating = gross rating minus on site consumption of power

G = gross rating

* = .8 of total flow is controlled to 82 percent level

Sources:
(1) Roberts, Edwin, 1980, phone communication to Arizona Public Service Company, June 30; (2) Christian, John, 1980, personal communication to National Park Service, Air Quality Office, June 2; (3) Copeland, John O., 1979, EPA memo to Steve Eigsti, July 17; (4) Noon, Don, 1980, phone communication to Salt River Project, July 9; and (5) Syzedek, Laura, 1980, personal communication to Nevada Power Company, June 19.

The two sizes are sometimes the net and gross ratings, respectively. Some refer to maximum possible electrical output while others refer to the normal output. These differences are small enough to neglect for the purpose of this study. Each generating unit is listed separately because we must account for the great variation of size, control equipment and SO_2 emissions that sometimes exists between units of the same power plant.

The controlled emission rate of SO_2 is reasonably well known for these sources. A list of units proposed to operate by 1990 is presented in Table 5. The projected SO_2 emissions for these units are not so readily available. Each utility company was requested to provide emissions by phone or letter if there existed no report with the information.

Using the relations for $\frac{d\alpha_{fp}}{dE_{SO_2}}$ and $\frac{d\chi_{fp}}{dE_{SO_2}}$, the increase in controlled SO_2 emissions will cause the concentration of fine particulate to increase by

$$\Delta\chi_{fp} = 0.19\text{-}0.20\ \mu gm^{-3}$$

This change is small, but must be translated into the change in apparent contrast of specific targets in order to judge perceptibility. Perceptible changes are required in order to ask people questions about their economic willingness to pay to prevent such changes. Selected locations and targets are listed in Table 6 along with the information used to compute contrast change. Equation 4 is used in the form

$$C_r = C_o e^{-(k\chi_{fp}+\bar{\alpha}_R)r}.$$

The change in the apparent green contrast between columns 7 and 8 of Table 6 cannot be perceived (Maim, et al., 1980a). This finding suggests that the addition of 392-410 tons of SO_2 per day to this region would be insignificant to visibility. For comparison, the 1979 SO_2 emissions from copper smelters in southern Arizona were 2400 tons per day, almost 5 times as much (Billings, 1980). Another approach is to compute an artificially larger scenario that causes a perceptible change in contrast which could be used in a questionnaire.

Scenario 2

The current and proposed power plants for the test region will be supposed to emit SO_2 at the maximum possible uncontrolled rate. Direct particulate emissions will continue to be controlled. The uncontrolled SO_2 emissions are listed in Tables 4 and 5. The increased emissions would be 3692-4327 tons per day. These uncontrolled SO_2 emissions would cause $\Delta\chi_{fp} = 1.48\text{-}1.73\ \mu gm^{-3}$ over the summer 1979 fine particulate concentrations listed in Table 6. The changes in apparent contrast shown in column 9 of Table 5 vary between .05 and .09, and are perceptible changes (Maim, et al., 1980a).

The actual photographs used in the summer 1980 perception/economic survey are listed in Table 3 with information on the target name, time of day, inherent

Table 5

Major SO_2 Sources Proposed for Test Region by 1990

Name	Unit	Power (mw)	Sulfur Dioxide Control Level %	Sulfur Dioxide Control Level (pounds SO_2 per 10^6 BTU)	SO_2 Emission Rate (tons per day) Controlled	SO_2 Emission Rate (tons per day) Uncontrolled
Harry Allen[1]	1 2 3 4	500 500 500 500	92 92 92 92	.17 .17 .17 .17	10 10 ID 10	129 129 129 129
Green River	·	1000	90	.2	25	250
Werner Valley[1]	1 2	250 250	92 92	.17 .17	5 5	65 65
Garfield	1	400	90	.2	10	100
Inter-Mountain	1 2 3 4	750(N)-820(G) 750(N)-820(G) 750(N)-820(G) 750(N)-820(G)	90 90 90 90	.2 .2 .2 .2	18-20 18-20 18-20 18-20	184-200 184-200 184-200 184-200
Hunter	3 4	400-430 400-430	90 90	.2 .2	10 10	100-106 100-106
Colorado	1	250	90	.2	6	61
Cholla	3 4 5	242-289 350-375 350-375	90 90 90	.06-.07 .07 .07	2 3[2] 3[2]	20 30 30
Coronado	2 3	350-395 350-395	66[a] 66	.8[3]-9 .8[3]-9	38[2,3]-43 38[2,3]-43	113-127 113-127
Springerville	1 2 3	350 350 350	60 60 84	.6 .6 .25	25[2,4] 25[2,4] 10[2,4]	62.5 62.5 61
Moon Lake		800	90	.2	20	200
San Juan	4	500	67	.55	35	106
Plains Electric	1	210	90	.2	5	50
New Mexico G.S.	1 2 3 4	500 500 500 500	80 80 80 80	.34 .34 .34 .34	21 21 21 21	105 105 105 105
Reid Gardner	4	250-295	85	.14-.16	10	67
Totals	33 units	12,704-13,480			481-499	3328-3432

[a] Only 80 percent of total flow is directed through wet scrubbers with 82 percent control

N = net

G = gross

Sources:
(1) Syzedek, Laura, 1980, personal communication to Nevada Power Company, June 19; (2) Energy Impact Associates, 1979, Update Report; (3) Noon, Oon, 1980, phone communication to Salt Rive Project, July 9; and (4) Fleck, Lowell, 1980, phone communication to Tucson Electric Power Company, July 11.

Table 6

Apparent Green Contrast Change to be Caused in Test Region by Proposed Sources of SO_2

Location	Target	Time of Day	Median Fine Particulate Concentration (μgm^{-3}) Summer 1979	Median Fine Particulate Concentration (μgm^{-3}) 1990-1995 Scenario 1	Median Fine Particulate Concentration (μgm^{-3}) 1990-1995 Scenario 2	Median Apparent Green Contrast Summer 1979	Median Apparent Green Contrast 1990-1995 Scenario 1	Median Apparent Green Contrast 1990-1995 Scenario 2
Grand Canyon	Trumbull Mountain	9 a.m.	1.92	2.12	3.40-3.65	-.12	-.11	-.06,-.05
"	"	3 p.m.	1.37	1.57	2.85-3.10	-.17	-.15	-.08,-.07
"	Desert View	9 a.m.	2.60	2.80	4.08-4.33	-.45	-.44	-.36,-.35
Mesa Verde	Lukachukai #1	9 a.m.	1.86	2.06	3.34-3.59	-.10	-.09	-.05,-.04
Zion	Trumbull Mountain	9 a.m.	1.82	2.02	3.30-3.55	-.12	-.11	-.06,-.05

contrast, Rayleigh attenuation coefficient, distance between the observer and the target, archive number, apparent contrast measured with a teleradiometer on the slide image projected on a screen, and the associated fine particulate concentration.

The regional analysis of the change in visibility from the current (summer 1979) median to the 1990 uncontrolled SO_2 emissions used the slides listed in Table 7, whose specifications are listed in Table 3.

D. Conclusions

The photographs collected in a regular photographic monitoring program over a period of at least half a year are numerous and varied enough to provide sets for surveying purposes. The photographs can be presented as slide images on a screen (Maim, et al., 1980a) or as prints. The frequency of occurrence of each photograph can be computed roughly from the photograph collection (Walther and Carey, 1980) or from the set of teleradiometer measurements of the apparent green contrast of a target in the scene. The apparent green contrast of the target in each photograph differs from the adjacent photographs in its subset by .02 to .12. These differences are perceptible, but they are not uniform because the photographic monitoring period was not long enough to produce every desired apparent contrast with the constraints of blue sky and no snow on the target. Photographs with these constraints and with perceptibly different contrasts allowed people to be questioned about the economic value of different visual air quality.

The locations of the EPA/NPS regional visibility monitoring program cameras and teleradiometers constrained the region that could be chosen for the scenarios of future changes that may affect visibility. The test region represents an area where good visibility is probably necessary for the high social value people place on the region's many national parks and monuments. Coal-fired power plants are the most numerous future sources of air pollution proposed for this test region and they have been the most controversial air pollution sources in the past history of this region. Because fine particulate is the single most important kind of pollutant affecting visibility in this region (Waggoner, et al., 1981) and because SO_2 emissions are the most important contribution to fine particulate, (White and Roberts, 1977) visibility will here be directly related to SO_2 emissions. This relationship was developed by others on the basis of airport visibility observations and the SO_2 emission inventory history of the southwest (Marians and Trijonis, 1979). As such it is a rough model, but it is consistent with the roughness of the economic information obtained by asking people how much they would be willing to pay on their monthly power bills to protect visibility.

One scenario of the future suggests no deterioration of visibility because smelter SO_2 emissions near the test region may decrease more than the SO_2 emissions may Increase from proposed coal-fired power plants. This scenario provides no basis for the survey process. A second scenario based on the actual SO_2 emissions expected from the proposed power plants suggests there will be no perceptible deterioration of visibility, again providing no basis for a survey. The third scenario is hypothetical, based on the totally uncontrolled

Table 7

Slides in Regional Scenario of Uncontrolled SO_2 Emissions

Location	Target	Slides: Current Median	Slides: 1990 Scenario Uncontrolled SO_2
Zion	Trumbull Mt.	Z190	z16
Mesa Verde	Lukachukai 1	MV133	MV48
Grand Canyon	Desert View	GC94	GC501

release of all SO_2 that can be created from the sulfur in the coal for both existing and proposed power plants. The r,egression-based relationship of visibility and SO_2 emissions is combined with this hypothetical scenario to compute a perceptible deterioration of visibility from the middle photograph of each vista to the next worse photograph. This change allows comparison of the value of the visibility increment to the cost of air pollution equipment needed to reduce the uncontrolled emissions to the actually projected level of control.

All three scenarios of future SO_2 emissions in the test region should be recomputed with the use of a long range transport model, allowing for: 1) the transport of distant emissions into the region; 2) the chemistry of SO_2 conversion to sulfate fine particulate; 3) the removal by dry and wet deposition of pollutants affecting visibility; and 4) the inclusion of smelter and urban emissions.

CHAPTER 4

PERCEPTION OF VISIBILITY

A. Introduction

Valuing visibility in economic terms requires a clear understanding of how people perceive visual air quality. This chapter summarizes our current understanding of perception of visibility and presents some new results of a study utilizing photographs similar to the ones used in the economics portion of the study.

Visibility is commonly interpreted as visual range, which roughly speaking, is the distance an observer would have to back away from a target for it to disappear. Visual range cannot be measured directly, nor is it necessarily representative of what an observer "sees." More importantly, visibility involves human perception of color, form and texture of near and distant natural structures.

0. Summary of Perception Studies

Characterization of visibility involves a selection of physical variables that can be directly measured and correlated with human perception of changes in visual air quality. Previous field experiments have examined the relationships between physical parameters of visibility such as apparent target contrast, color contrast, sun angle, and human perception of changes in those parameters (see Maim, et al., 1980a,1980b). These studies also addressed human perception of changes in air quality as presented in different media, comparing observer judgments of color slides, color photographs, and the actual scene as viewed on-site.

The original study which examined these variables was conducted by the National Park Service (NPS) and Environmental Protection Agency (EPA) at Canyonlands National Park during the summer of 1979. Visitors to the Island in the Sky District of the park were asked to rate color slides representing variations in air quality, sun angle, meteorological conditions, ground cover, and landscape elements. It was assumed, a priori, that such variables would be important factors affecting human perception of visual air quality. Thus, these factors were specifically controlled so that the effect of changes in air pollution on perceived visual air quality could be explicitly studied. This approach may be contrasted to that of randomly sampling the joint occurrences of all of these variables and then, a posteriori, attempting to separate their effects by means of statistical regression procedures (Latimer, et al., 1980). Both approaches can make valid and valuable contributions to the understanding of visibility perception. Where a purely statistical approach may have problems in explicitly extracting the targeted relationships between per ception of air quality and electro-optical parameters, it may achieve greater generalization in predicting the effects of illumination and meteorological conditions.

The study slides, all of the same scene, were chosen from over 1000 slides taken throughout the previous year as a part of the NPS/EPA visibility monitoring program. At the time each slide was taken, teleradiometer readings of apparent target contrast, color contrast, and various meteorological measurements were made. Therefore, for each slide rated by visitors, the physical and optical parameters of air quality were known. After viewing 10 preview slides representing the full range of air quality conditions, visitors rated 48 evaluation slides on a 1 to 10 scale, with 1 representing very poor visual air quality and 10 representing very good visual air quality. Interspersed with the 48 evaluation slides were 15 control slides used to determine the precision with which each visitor used the rating scale. After rating the slides, visitors completed a demographic questionnaire and were administered a test for color-blindness. Finally, they entered a second room of the survey trailer where they could view the La Sal Mountains through a window, framed much like the slides. The visitors were then asked to rate the visual air quality on that day as viewed through the window on the same 1 to 10 scale used for rating the slides. A color slide and teleradiometer reading were taken to correspond with each on-site rating. Later in the survey period, these slides were shown to visitors, who again rated visual air quality on the 1 to 10 rating scale. Nearly 700 visitors completed the survey.

Studies similar to the Canyonlands study were conducted at Mesa Verde and Grand Canyon National Parks during the summer of 1980. The differences include:

- Where the Canyonlands study used only one scene, the 1980 studies utilized several vistas located in different national parks;

  where the first study allowed visitors to rate a three dimensional scene constrained by a window to mimic the identical scene as viewed in the slides, the 1980 studies allowed the visitor to rate physically unrestricted views of a vista in the same general direction as the slides were taken. These on-site ratings were then compared to ratings (by other observers) of color slides;

- where the Canyonlands study reported results for all visitors combined as a group, the later studies specifically investigated the effects of a number of social and demographic characteristics on judgments of perceived visual air quality;

  where the 1979 study focused primarily on a determination of a humanly perceptible amount of change in visual air quality, the 1980 studies also examined social and economic issues associated with changes in visual air quality;

and, where the first study compared only visitors' judgments of changes in air quality shown in color slides and the actual scene, the 1980 studies compared visitors' judgments of air quality represented in color slides, the actual scenes, and color prints.

C. Study Results

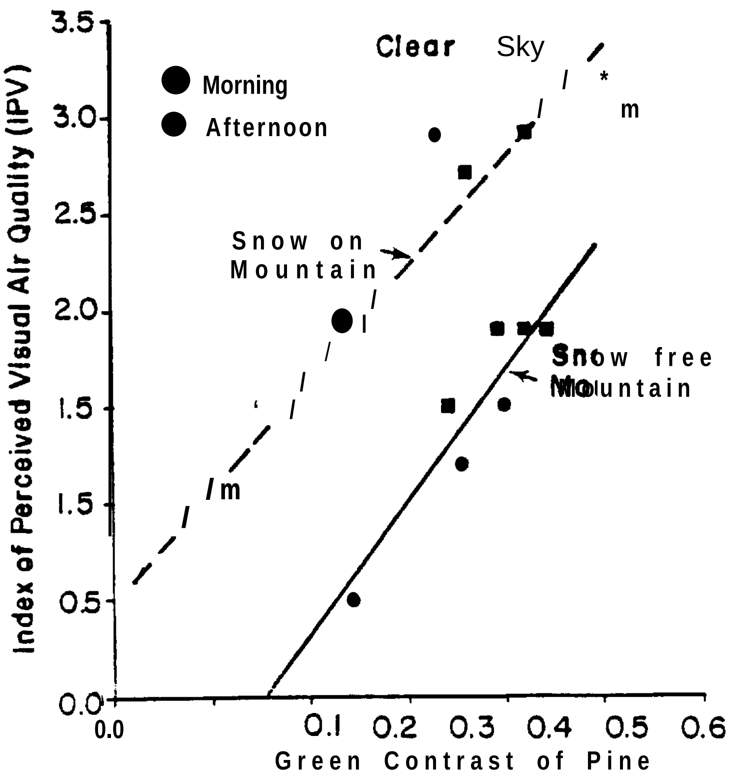
Visitors used the 1 to 10 rating scale with precision, as is evidenced by their ratings of the 15 control slides used in the Canyonlands study. The control slide mean rating (CSMR) for 50, 100, or 300 observers varied by less than .01 and the mean of their standard deviations varied by less than 0.4. Similar analysis of the evaluation slides shows almost identical results. Generally speaking, slides with extremely good or extremely poor visual air quality were universally rated the same by all observers. Slides which represented intermediate levels of visual air quality were more difficult to rate; control slide ratings indicated that some observers tended to be extremely precise and consistent in their ratings while others had more difficulty in using the rating scale. It is important to note, however, that the average rating given each slide by a series of observers did not change when those observers with a control slide standard deviation (CSSD) of greater than 1.0 were eliminated from the data set, nor did the introduction of more observers, beyond approximately 50, change the average rating given each slide.

There was, however, an ordering effect when a slide representing average visual air quality was preceded by a slide representing extremely good or poor visual air quality. This effect was minimized by reversing the order of the slides half-way through the study period. Thus, a slide that initially followed an extremely good or poor slide, would be evaluated first, normalizing the overall slide ratings.

There seemed to be little or no difference in the way observers with different demographic backgrounds used the rating scale. However, a Z-score analysis was carried out to minimize the effect of variations between individual observers. This Z-score analysis then allowed for calculation of Indexes of Perceived Visual Air Quality (IPV's).

Figure 5 is a plot of mean IPV's versus apparent target contrast, C_G, at 550nm (as measured by a multiwavelength teleradiometer) for clear sky days (99 percent confidence limits around the mean is $\pm$ 0.11). The broken and solid lines correspond to snow and tree covered scenes, respectively. It is evident that the functional relationship between Perceived Visual Air Quality (IPV) and contrast (C_G) is linear. The correlation coefficients, significant at the 99 percent confidence level, between IPV and C_G for the six meteorological and air quality conditions measured are presented in Table 8.

Figure 5



Graph of the index to Perceived Visual Air Quality (IPV) as a function of apparent target (tree covered portion of the La Sal Mountains) contrast for the clear sky condition. The dotted and solid line are for snow covered and snow free conditions, respectively while (●) AND (■) indicate slides that were taken in the morning and afternoon, respectively.

Table 8. Correlation Coefficients between IPV and C_G

	Clear Sky	Cumulus Clouds	Overcast Sky"
Snow covered mountain	0.93	0.93	0.94
Green mountain	0.90	0.98	0.93

This functional relationship can be expressed as follows:

$$IPV = mC_G + b$$

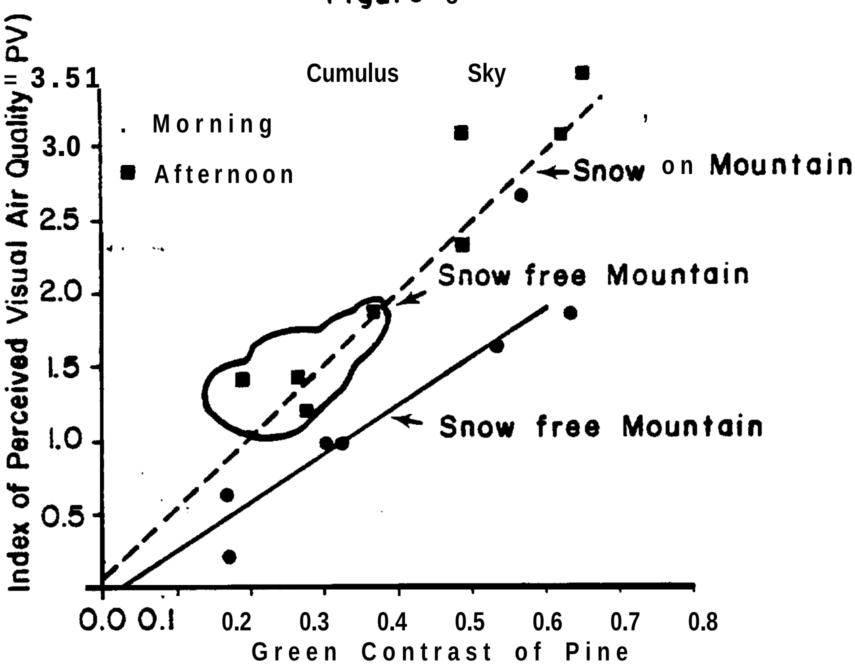
where IPV is the Index of Perceived Visual Air Quality, C_G is apparent target contrast (tree covered mountain in this case), b is the y-intercept, and m is an index indicating the sensitivity of a given vista to changes in air pollution. The sensitivity of a vista to the impact of air pollution, then, is the slope of the IPV vs. C_G curve; the steeper the slope, the more sensitive a vista is to incremental changes in air pollution. Upon comparison of the slopes of the curves shown in Figures 5, 6 and 7, it is clear that cumulus clouds and overcast cloud conditions cause m to decrease; with m being the lowest for the cumulus cloud condition. Clouds tend to obscure the effects which increased air pollution has on perceived visual air quality.

Perceived visual air quality of a vista under clear sky conditions seems to be most sensitive to changes in amounts of air pollution. In addition, snow in a vista appears to increase the observer's rating of visual air quality for all sky conditions. It should be noted that even though an observer's rating of visual air quality increases with a snow covered mountain (indicating greater scenic quality), the sensitivity of that vista to contrast change, and thus air pollution, remains approximately the same for different meteorological conditions.

It is important to understand that changes in apparent target contrast due to increased air pollution are dependent on the amount of pollutants in the existing atmosphere. In a clean atmosphere, a small increase in particulate concentration will cause a large decrease in contrast, while in a relatively dirty atmosphere that same increase in particulate concentration may not be perceptible. Figure 8 graphically shows the expected change in contrast resulting from additions of 2 micrograms per cubic meter ($\mu g/m^3$) fine particulate (0.1 μ - 1.0 μ diameter particles) to atmospheres containing approximately 0, 4, 8 and 18 $\mu g/m^3$ fine particulate as a function of vista distance. It has been assumed that an attenuation coefficient of 0.01 km^{-1} is equivalent to a fine particulate concentration of 2 $\mu g/m^3$. It is clear in all cases that the cleaner the existing atmosphere, the more sensitive it is to an incremental increase in particulate loading.

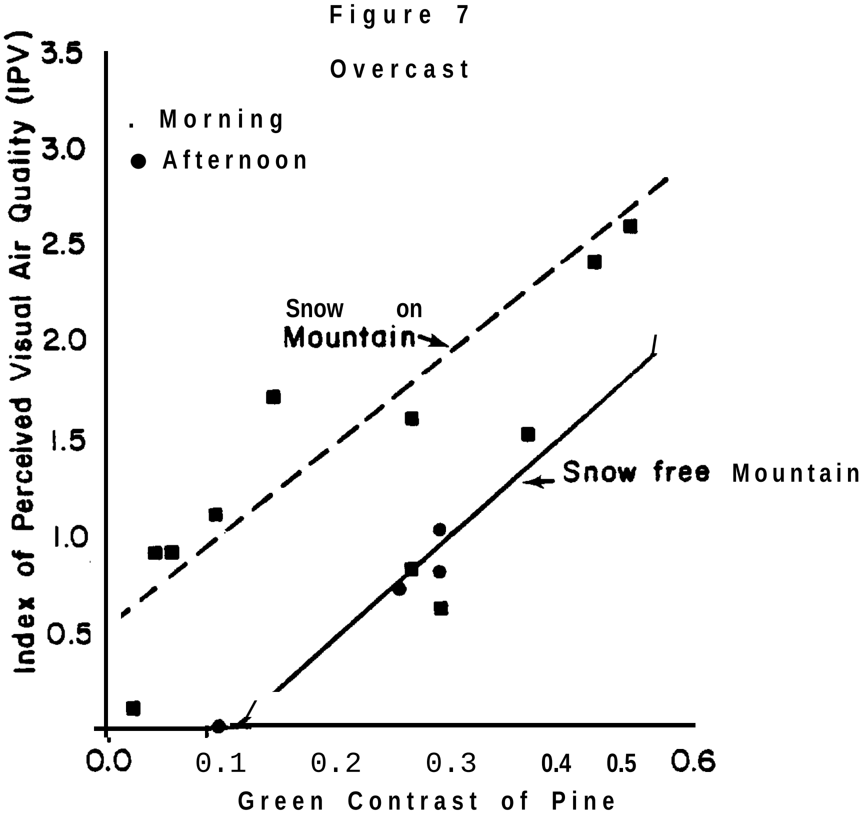
Also, as shown in Figure 8, the maximum sensitivity to incremental increases in air pollution occurs at a vista distance of about 60-100 kilometers in a clean atmosphere. In an atmosphere containing 18 $\mu g/m^3$ particulate this distance of maximum sensitivity decreases to 10 kilometers.

Figure 6



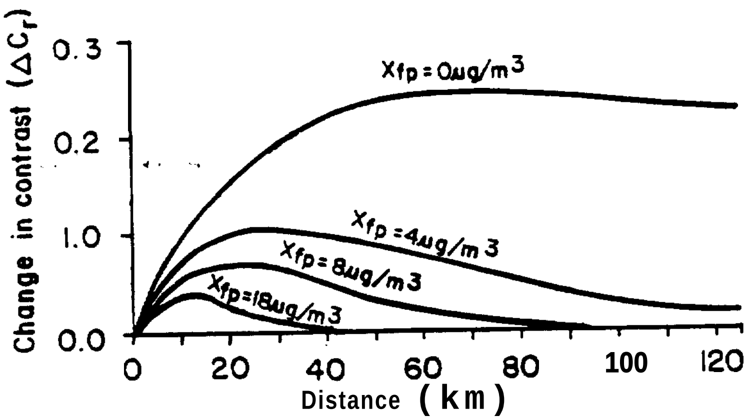
Same as Figure 5 but for cumulus cloud conditions.

Figure 7



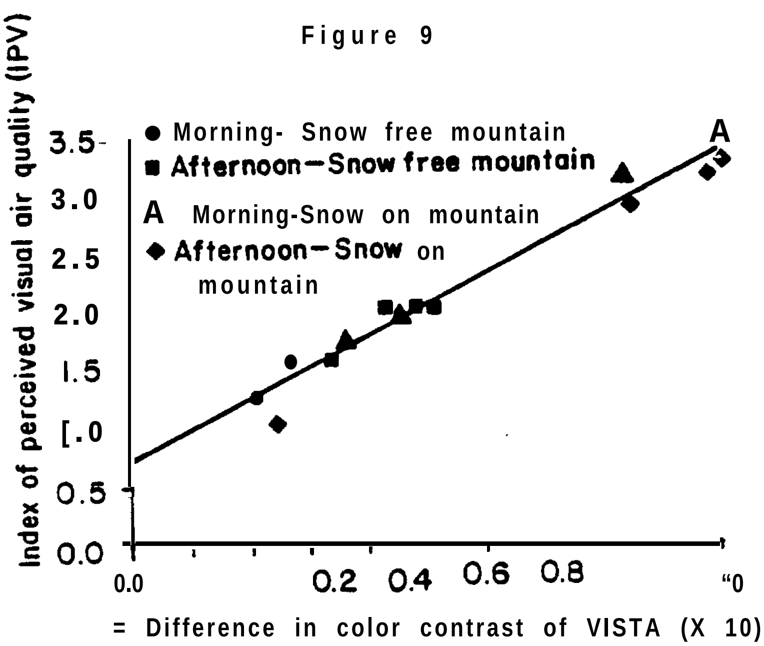
Same as Figure 5 but for overcast cloud conditions.

Figure 8



A plot of contrast change resulting from an increase in fine particulate concentration of 2 ug/m^3 as a function of vista distance for initial loadings of 0.0, 4, 8 and 18 ug/m^3.

Figure 9



Graph of I PV versus change in overall vista color. Indices of perceived visual qir quality presented in this graph, were derived from visitor's ratings of the morning and afternoon, snow, and no snow, clear sky conditions.

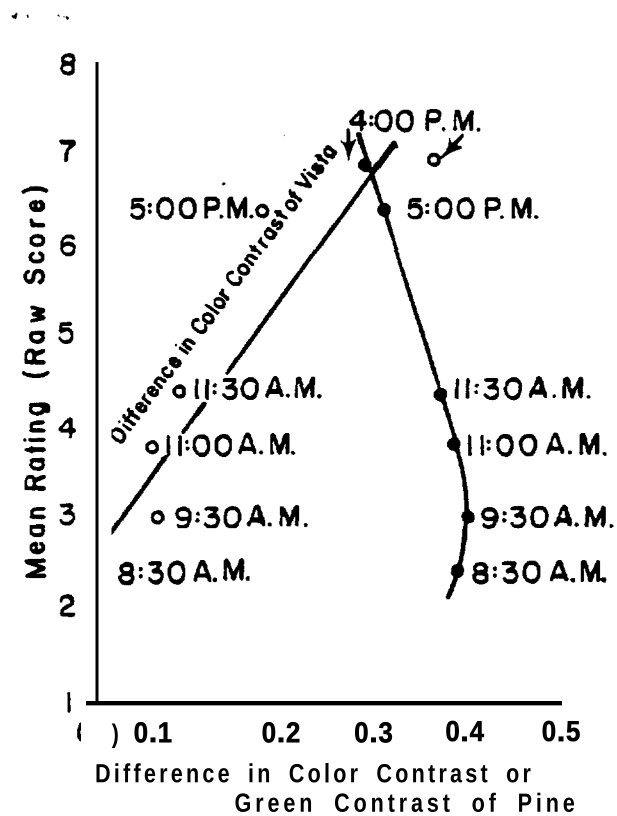
Results of the Canyonlands study also indicate that any increase in color of the total vista results in increases in the IPV. The change in overall color contrast, ΔC_T, for each slide was plotted against the IPV, indicating the linear relationship shown in Figure 9. The observer rated the visual air quality of a scene in direct proportion to the amount of color present.

Sun angle plays an important role in vista color and observer's judgments of visual air quality. Visitors were asked to rate a series of slides of the La Sal Mountains which were taken starting at 8:00 a.m. and continuing until 4:00 p.m. The air pollution as measured by a teleradiometer and an integrating nephelometer remained unchanged throughout the day. The canyon walls in the mid-foreground of the scene were in complete shadow at 8:00 a.m. The color of the canyon walls continually increased as the day progressed and the sun angle changed. As more color appeared in the scene, observers gave it a higher rating of visual air quality. Figure 10 shows this relationship, plotting the mean slide rating (raw score) for 50 observers as a function of color contrast for the green portion of the La Sal Mountains. Time of day is indicated next to each data point. During the course of the day, the contrast at 550nm actually decreased because of a decrease in inherent contrast, while the mean rating of the slides increased. However, the relationship between change in color contrast and perceived visual air quality remains linear. The correlation coefficient between these two variables is greater than 0.9, significant at the 99 percent confidence level. This relationship also appears to be independent of the demographic characteristics of the observers.

Once these physical and perceptual relationships are established, it is important to analyze the relationships between human perception of changes in visual air qual ity as represented in different media. Do observers perceive changes in visual air quality in an actual on-site situation with the same precision as they would perceive the same amount of change as shown on a color slide? In order to examine this question, visitors in the Canyonlands study rated 40 slides that had been taken during on-site ratings earlier in the study period. The optical and meteorological data for the approximately 400 on-site ratings were inspected to locate cases representing sun angle, meteorological and air pollution conditions as near as possible to those in each of the 40 slides. For some slides, several corresponding on-site ratings were found. A student t-test was used to determine whether the slide ratings were statistically different from on-site ratings. Since the test was applied to the null hypothesis that the two samples being compared were drawn from the same population, calculations were made to determine the probability of the difference between means of on-site and slide ratings having a value as large as, or greater than observed. The null hypothesis being examined assumed that the two samples belong to the same population, consequently, the two variance estimates must not be significantly different. This hypothesis was examined by means of the F-test.

Results of the comparisons are summarized in Table 9 while a scattergram of the on-site and slide ratings is shown in Figure 11. The first column of Table 9 gives the time that the slide was taken; it is also the time, ±30 minutes, that the on-site ratings were made. Column two is a meteorological code indicating the cloud cover present at the time the photograph was taken;

Figure 10



Mean rating (raw scene) of a series of six slides that were taken of the La Sal Mountains, starting at 8:00 A.M. and continuing until 5 P. M., as a function of color contrast change of the vista (o) or apparent target green contrast of pine covered portion of the vista (●).

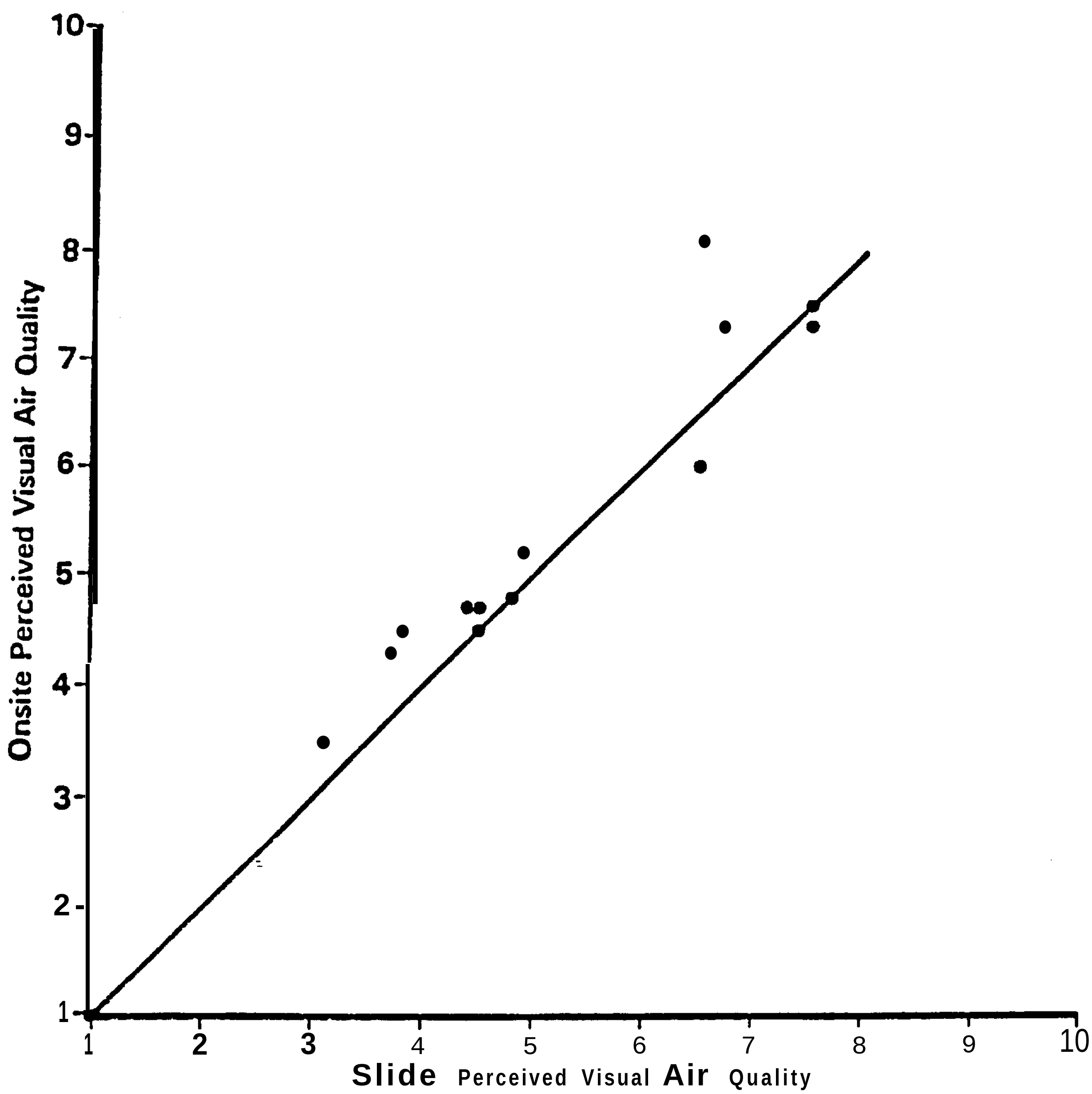
Table 9

Statistical Analysis of On Site and Slide Ratings

Time	Sky Code	Green Cont.	Slides Nobs	Slides Mean	Slides SD	Slides 95%-CL	On Site Nobs	On Site Mean	On Site SD	On Site 95%-CL	Tests T	Tests T(Crit)	Tests F	Tests F(Crit)
1000	2	.34	22	3.1	1.6	.66	8	3.5	1.9	1.36	.574	2.05	1.451	2.4
1030	1	.40	208	4.5	1.7	.24	13	4.5	1.5	.84	.080	1.96	1.274	2.1
1100	0	.38	45	3.8	1.2	.37	10	4.5	1.4	.86	1.631	2.00	1.273	2.8
1100	2	.33	22	4.5	1.7	.71	17	4.7	1.9	.94	.354	2.00	1.287	3.0
1130	1	.36	45	4.4	1.2	.37	21	4.7	1.4	.60	.944	1.96	1.329	2.4
1130	2	.34	22	4.9	1.4	.59	18	5.2	1.8	.86	.523	2.00	1.696	2.8
1130	5	.34	22	4.8	1.3	.57	9	4.8	1.6	1.04	“.041	2.05	1.446	3.35
1130	4	.19	22	3.7	1.1	.48	9	4.3	1.1	.75	1.449	2.05	1.033	3.35
1330	2	.30	208	6.5	1.8	.25	15	6.0	2.1	1.07	1.029	1.96	1.323	2.04
1330	2	.33	208	7.5	1.8	.25	23	7.5	1.1	.45	.057	1.96	2.769	1.79
1400	0	.36	45	6.5	1.4	.42	13	8.1	1.0	.53	3.802	2.00	2.153	2.66
1400	0	.35	160	7.5	1.6	.26	8	7.3	-9	.63	.438	}.96	3.258	2.51
1400	0	.35	160	6.7	1.7	.27	8	7.3	.9	.63	.907	1.96	3.678	2.51

Figure 11

Average perceived visual air quality ratings of 13 different three-dimensional scenes are plotted against corresponding ratings of slides that represented those same scenes.



0 = cloudless skies; 1 = no clouds in the plane of the observer, sun, and vista; 2 = 0 to 1/3 cloud cover; 3 = 1/3 to 2/3 cloud cover; 4 = 2/3 to full cloud cover; and 5 = overcast. Column three is the apparent target contrast at 550nm of a forested section of the La Sal Mountains on the day when the slide was taken; it is also the apparent target contrast +0.01 of that same portion of the vista on the days that the three dimensional-on-site ratings were made. Columns four to seven are the number of observations, arithmetic mean, standard deviation, and 95 percent confidence interval of the slide ratings, and columns eight to eleven give the same statistics for the on-site ratings. Columns twelve and fourteen are the t and F statistic while columns thirteen and fifteen are the associated "critical" values which the t and F number should not exceed for a 5 to 1 percent level of significance respectively. These calculations were carried out only if there were at least 8 on-site ratings.

An examination of the F-test shows that of 13 populations that were compared, the F value exceeds its critical value 3 times. For the remaining 10 populations the difference between the variances is not significant at the one percent level. If the calculated t value is greater than the tabulated critical value (5 percent level of significance), the null hypothesis is rejected and the conclusion is that the difference between the on-site and slide rating is significant. Or conversely, if the value of t is less than the critical value it is concluded that there is no statistically significant difference between on-site and slide ratings. In only one case is the calculated t value greater than its associated critical value. Thus, there are 9 comparisons of on-site versus slide ratings that show no significant difference between their means.

The previous statistical tests do not prove that the means of on-site and slide ratings are the same, only that they are not statistically different. However, the analysis in conjunction with a fairly high correlation of 0.94 between the on-site and slide ratings and the close proximity of the data points to the line that shows where they would fall if there were a one-to-one correspondence, seems to indicate that when the actual scene is confined to the same form as that of the slides, slides are good substitutes for the actual three dimensional scenes.

For research design purposes, it is also important to know if observers perceive changes in visual air quality as shown in color prints with the same precision as they perceive changes shown on color slides. In the 1980 Grand Canyon study, groups of observers were asked to rate sets of 30 randomly ordered 8 X 10 inch color prints on a 1 to 10 scale. Two sets of photographs were rated; one set contained Mt. Trumbull scenes under differing ground cover, meteorological and air quality conditions, while the other photographic set contained Desert View scenes under varying meteorological and air quality conditions (the Desert View data set did not contain any scenes with snow on the ground). Groups of observers rated the sets of 30 color slides from which the photographs were made. Mean ratings for all slides in each set were then compared to the mean ratings for each color photograph for groups of at least 50 observers. Comparisons were made by regressing the slide-based ratings (mean ratings on the 1 to 10 scale) on the ratings of the corresponding color photographs. Again, the relationship is a positive one, as indicated by a simple correlation coefficient of .96, significant at the 99 percent confidence level, between the slides and corresponding photographs used in the economic analysis.

D. Conclusion

These positive relationships of human perception of changes in visual air quality, whether viewed in a color slide, color print or on-site, allow for different research methods. It appears that it may no longer be necessary to conduct air quality perception research only in on-site situations. This finding enables researchers to conduct air quality perception studies in other environments throughout the country, with substantially' reduced costs, but more importantly, allows for a statistically random sample of observers which is not possible in on-site studies. It is important that researchers continue to examine these relationships in order to develop a valid model for the prediction of air pollution and scenic quality effects on perceptions of visual air quality.

CHAPTER 5

MEASURING THE ECONOMIC VALUE OF VISIBILITY

A. Introduction

Visibility is a pure public good as described by Samuelson (1954). The goal of Congress in passing the prevention of significant deterioration (PSD) amendments to the Clean Air Act was, in great part, provision of visibility in the National Parklands. However, utilities and other industries have claimed, quite correctly, that preservation of visibility (air quality) is costly. Do the benefits of preservation justify these costs? The purpose of this chapter is to provide a methodology for assessing the benefits of preserving visibility so that the question posed above can, in part, be answered.

Economists have used a number of techniques for valuing public goods. These include, first, direct costing wherein, for example, benefits of air pollution control could partly be measured as the reduced economic damage to material (e.g., paint), vegetation (including agriculture) and health (e.g., inure productive workers). A second technique called the hedonic approach uses an indirect method to value public goods by trying to associate changes in market prices with changes in public goods across locations. Thus, urban property value studies are typically utilized in areas of heavier air pollution. One can get an indication of how people value clean air by looking at the premium paid for homes in clean air areas. Both of these methods are described in detail by Freeman (1979) and Mäler (1974) but are not applicable to valuing visibility in rural recreation areas such as the National Parklands of the Southwest.

To develop value in such a situation, economists have turned to survey methods. A large literature has developed around the use of survey techniques in valuing visibility which includes, in part, early work by Randall, et al. (1974) and Brookshire, et al. (1976), and more recently work by Rowe, et al. (1980) and Brookshire, et al. (1980). This literature has been summarized in Schulze, et al. (1981) so we will not go into great detail here. However, it has been shown that-survey techniques do provide willingness to pay measures for air quality in an urban setting (Los Angeles) consistent with results of a hedonic property value analysis, lending support to the survey approach (see Brookshire, et al. [1982]). This last study is included as Appendix B.

Additionally, survey work with consumers has failed to show any evidence of strategic bias (Schulze, et al. [1981]) in valuing public goods. This result is in agreement with the work of Grether and Plott (1979) and Smith (1978) which also failed to find evidence of strategic economic behavior in experimental settings. A number of other biases which have long been recognized in the survey literature have been identified, but standard techniques developed in the political science, psychology and sociology survey literature have been employed to cope with them (see description of the survey procedure in the next section).

B. The Theoretical Basis - The Economics of Preservation

The goal of the PSD regulations is preservation of the natural environment. An integral part of the environment of the national parklands of the southwest is visibility, the ability to see both color and detail clearly over long distances. It has been shown that human perception of visual air quality is associated with the apparent color contrast of distant visual targets. As contrast is reduced, a scene "washes out" both in terms of color and in the ability to see distant detail. Chapter 3 has related decreases in apparent color contrast to air pollution, noting, of course, that only part of the regional air quality situation is attributable to identifiable man-made air pollution. Chapter 4 has quantified perception of visual air quality. We now attempt to specify how people value preservation of perceived visual air quality.

The existing literature in environmental economics suggests that preservation value has two possible components.

First, a scenic resource such as the Grand Canyon attracts large numbers of recreators. The quality of the experience of these recreators depends in great part on air quality, in that scenic vistas are an integral part of the Grand Canyon "experience". Thus, air quality at the Grand Canyon is valuable to recreators. We might call this economic value, or willingness to pay for air quality at the Grand Canyon that enhances the qual ity of the recreation experience, user value. Thus, recreators in the National Parklands of the Southwest should be willing to pay some amount to preserve air quality for each day of their own use if their recreation experience is improved by good air quality. Total annual user value is then, simply, the total number of annual users times the average number of days spent in the parklands by each user per year times the average value to users of preserving visibility per day. One hypothetical market for collecting user value is an increase in entrance fees to be used to finance preservation of air quality, i.e., purchase of air pollution control equipment. Survey questionnaires can be designed to estimate user value based on such a hypothetical market.

The second component of preservation value is termed existence value. Individuals and households which may never visit the Grand Canyon may still value visibility there simply because they wish to preserve a national treasure. Visitors also may wish to know that the Grand Canyon retains relatively pristine air quality even on days when they are not visiting the park. Concern over preserving the Grand Canyon may be just as intense in New York or Chicago as it is in nearby states and communities.

Thus, preservation value has two additive components, user value and existence value. However, it is difficult to construct even a hypothetical market to capture pure existence value. Rather one could imagine a lump sum fee added., for example, to electric power bills to preserve air quality in the Grand Canyon and the surrounding parklands. Such a hypothetical fee could capture total preservation value, the sum of existence plus user value, if used as the basis of a survey questionnaire. In fact, the survey described in the next chapter asked approximately one-third of the respondents a pure user value question (how much would they be willing to pay in higher entrance fees per day for visibility at the Grand Canyon or other parks) and the other two-thirds of the respondents how much would they be willing to pay as a higher monthly power bill to preserve visibility in the parklands, a total preservation value question. Clearly, if total preservation value is much larger than total user value, then existence values must be large.

From an economic-theoretical perspective, consumer preferences can be modeled as follows:

Let C^u = color contrast (visibility) during a visit to the site by a user household;

$\bar{C}$ = average color contrast over the year at the site;

V = number of visits per year by the household to the site;

D = distance of the household from the site;

m = cost per mile of travel;

Y = household income;

X = composite commodity;

q = quality of the visit, a function $q(C^u)$ of visibility during the visit;

$R = q \cdot V$ = quantity of recreation obtained at the site;

E = entrance fee per visit;

B = total lump sum preservation bid for visibility;

U = household utility, a quasi-concave increasing function $U(\bar{C},R,X,)$ of average yearly visibility, $\bar{C}$, recreation at the site, R, and consumption of the composite commodity, X.

In general, a household will wish to maximize utility,

$$U(\bar{C},R,X),$$

subject to the amount of retreat ion attained by visiting the site

$$R = q(C^u)V$$

which we assume is the product of the quality of the visit, a function of visibility during the visit, C^u, and the number of visits, V. Additionally where we take the price of the composite commodity as unity, the availability of the composite commodity is

$$X = Y - B - (E + 2mD)V$$

or income minus any lump sum bid for visibility, B, minus any expenditures for visiting the site which are the sum of entrance fees, E, and travel costs, 2mD, for each visit, V. Note, any costs other than travel costs could conceptually be lumped with E. We take V, X, R, B, and E to be non-negative as well.

To get at user value, we will first take B to be identically equal to zero. The first order condition for use, V, where we substitute the constraints into the utility function is then:

$$U_R q - U_x (E + 2mD) < 0 \quad .$$

Note that, with the terms rearranged, if

$$\frac{U_R}{U_x} < \frac{E + 2mD}{q}$$

then V = O. In other words, if the sum of entrance fees plus travel costs divided by quality (the r.h.s. above) exceeds the marginal rate of substitution between recreation and the composite commodity (the value of recreation which is the l.h.s. above), then visitation is zero for the household. Note then, that, where distance from the site, D, is large, V may well be zero, a corner solution. Thus, someone from New York may never visit the Grand Canyon and consequently have a zero user value as well. To show that user value is zero if visitation is zero let us assume that the entrance fee, E, is a function of visibility, C^u, so we have $E(C^u)$. The consumer can then have a first order condition over choice of C^u by paying $E(C^u)$. This condition is

$$V \cdot (U_R q' - U_x E') = 0.$$

If V > 0, the user will then have

$$\frac{U_R}{U_x} q' = E'.$$

So E' is a measure of marginal user value of visibility per visit. However, if V = O, the first order condition for C^u is satisfied without equality of $U_R q'$ and $U_x E'$, so E' measures nothing, i.e., is of no relevance to the consumer. Thus, logically, a change in entrance fees will measure marginal willingness to pay for visibility in use only for users.

To get at total preservation value, let us fix entrance fees at E" and allow households to make a lump sum bid, B, for visibility at the site where we also assume that $C^u = \bar{C}$. In other words, households assume that the expected visibility level for their visit, C", is the average visibility level, $\bar{C}$. Since we have made the household utility function purely dependent on visibility at the site, the marginal bid for better visibility (derived by holding the utility level constant and totally differentiating the utility function) takes the form

$$\frac{dB}{d\bar{C}} = \left(\frac{U_{\bar{C}}}{U_x}\right) + \left(\frac{U_{Rq'}}{U_x}\right)V$$

"a" "b"

where the term in brackets "a" is the pure marginal existence value and the term in brackets "b" is marginal user value per visit (shown to be E' above for users if an entrance fee is collected for visibility). Thus, the lump sum bid, B, "collects" both existence value and user value from the household. B is then a measure of preservation value. The survey questionnaire presented in the next chapter attempts to estimate both $E(\bar{C}^{U})$ and B(C) as defined above and thus provides measures of user and total preservation value.

The model developed in the paragraphs above focuses on the difference between pure user value and pure existence value. The notion of pure existence value was put forward by Krutilla (1967) as an outgrowth of the notion of option value developed by Weisbrod (1964). In particular, Weisbrod argued that a potential user who might never actually visit a particular national park in his lifetime might well be willing to pay to preserve the <u>option</u> of use over that lifetime. This notion simply adjusts the concept of user value (as developed in the model above) for uncertainty. In other words, a potential user who might never make the trip to the Grand Canyon might be willing to pay a kind of insurance premium to retain the option of future use. The notion of pure existence value is, however, totally different from user or option value, in that, knowledge of the continued existence of a pristine national park in and of itself provides satisfaction. Thus, although option value might accrue to individuals who might never visit the Grand Canyon, that value is still based on potential use. Alternatively, existence value has no basis in actual or potential use, rather only on knowledge of the continued preservation of a unique resource such as the Grand Canyon.

REFERENCES

1. This approach does not account for uncertainty over visibility conditions, but will suffice for our purposes here. A model incorporating uncertainty would replace the user value notion with an option value measure.

CHAPTER 6

SURVEY DESIGN

. . . .

A. Introduction

The survey instrument addressed a multiple set of issues in the problem of valuing visibility in the national parklands. First, the parklands are unique national treasures and part of the national heritage. Thus, the parklands and their characteristics (i.e., visibility) might be valued by all citizens, whether or not they have or ever will visit the area. The survey instrument elicited valuations for actual users--in the national parklands. Second, new and current industrial facilities in the southwest impact not only specific parks but potentially could contribute to a regional deterioration of visibility. The survey instrument as a result of this local versus regional deterioration problem addressed the valuation of visibility in the Grand Canyon as well as in a regional scenic setting which included Mesa Verde and Zion National Parks. Figure 12 depicts a regional map showing the relative location of the three national parks, and their proximity to a partial list of existing and proposed industrial facilities in the southwest.

The following subsection will consider general aspects of the overall questionnaire design. Later subsections will address the actual mechanics of the valuation questions. Appendix C includes the complete survey instrument.

B. Survey Instrument Structure

The survey instrument follows, in general, the design that is set forth by Randall et al. (1974) and Brookshireet al. (1976). A hypothetical market is established around a well defined nonmarketed good for the respondent and a bidding vehicle is utilized. However, rather than a suggested initiation point for the bidding process, a set of columns representing varying amounts are given to the respondent enabling him to check the appropriate bid. This alleviates the potential for starting point bias as described in Brookshire et al. (1976) and empirically observed in Rowe et al. (1980). No specific mechanisms were incorporated into the questionnaire for other bias checks. In general, biases have not been found to be a systematic problem in bidding games. For a summary and analysis of bidding games in general and those exploring bias problems see Schulze et al. (1981).

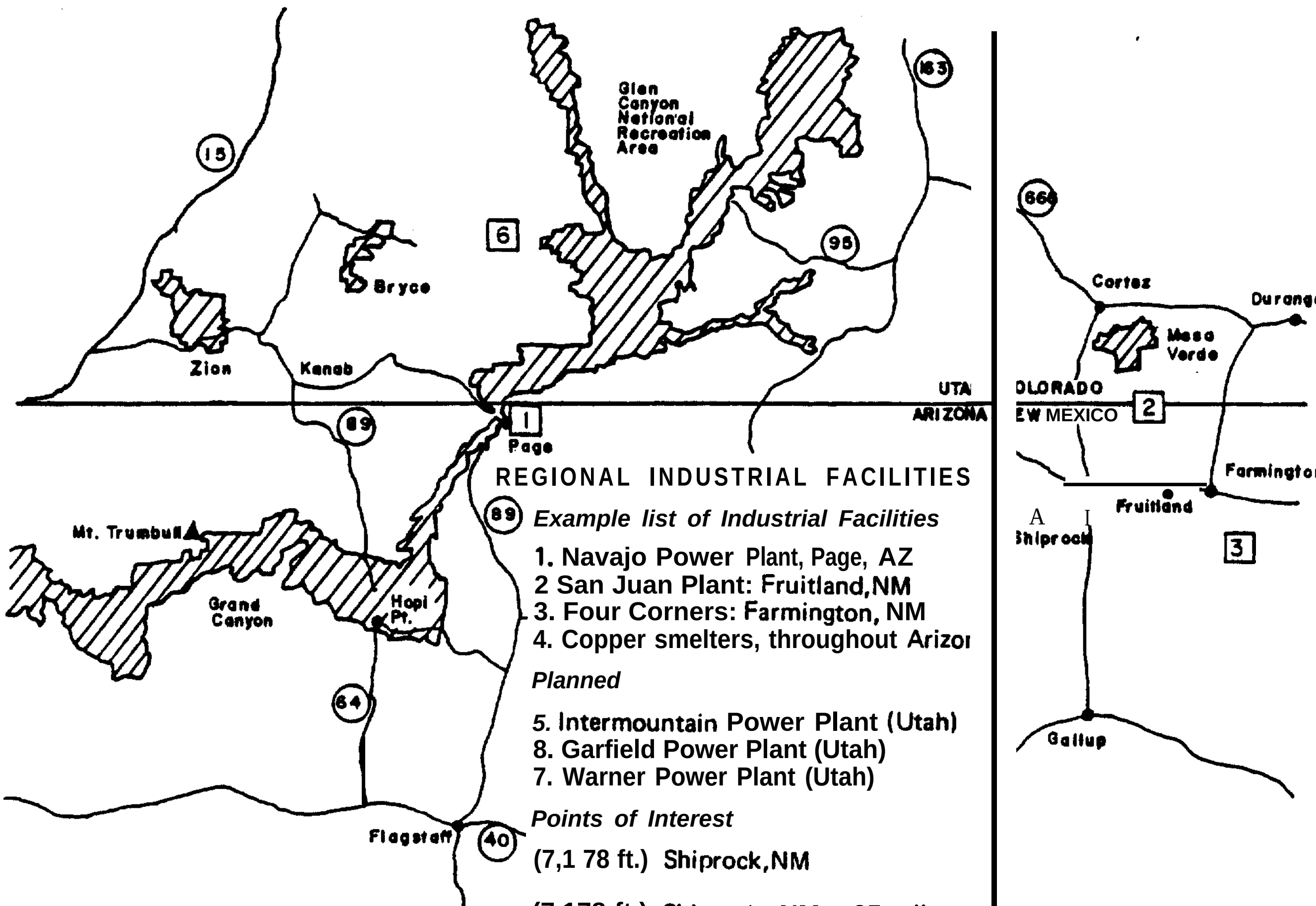
Figure 13 presents the basic flow of information gathered by the survey instrument. A brief introduction explaining the causes of poor visibility and an explanation of the photographs of the Grand Canyon was presented to each household. (See Chapter 2 for a complete discussion of the photographs.) After the introduction, past and proposed future use by the household for the Grand Canyon, Zion, Mesa Verde, Bryce, and Canyonlands National Parks was

5

Figure 12

REGIONAL MAP

7



REGIONAL INDUSTRIAL FACILITIES

Example list of Industrial Facilities

1. Navajo Power Plant, Page, AZ
2 San Juan Plant: Fruitland,NM
3. Four Corners: Farmington, NM
4. Copper smelters, throughout Arizo

Planned

5. Intermountain Power Plant (Utah)
8. Garfield Power Plant (Utah)
7. Warner Power Plant (Utah)

Points of Interest

(7,1 78 ft.) Shiprock,NM

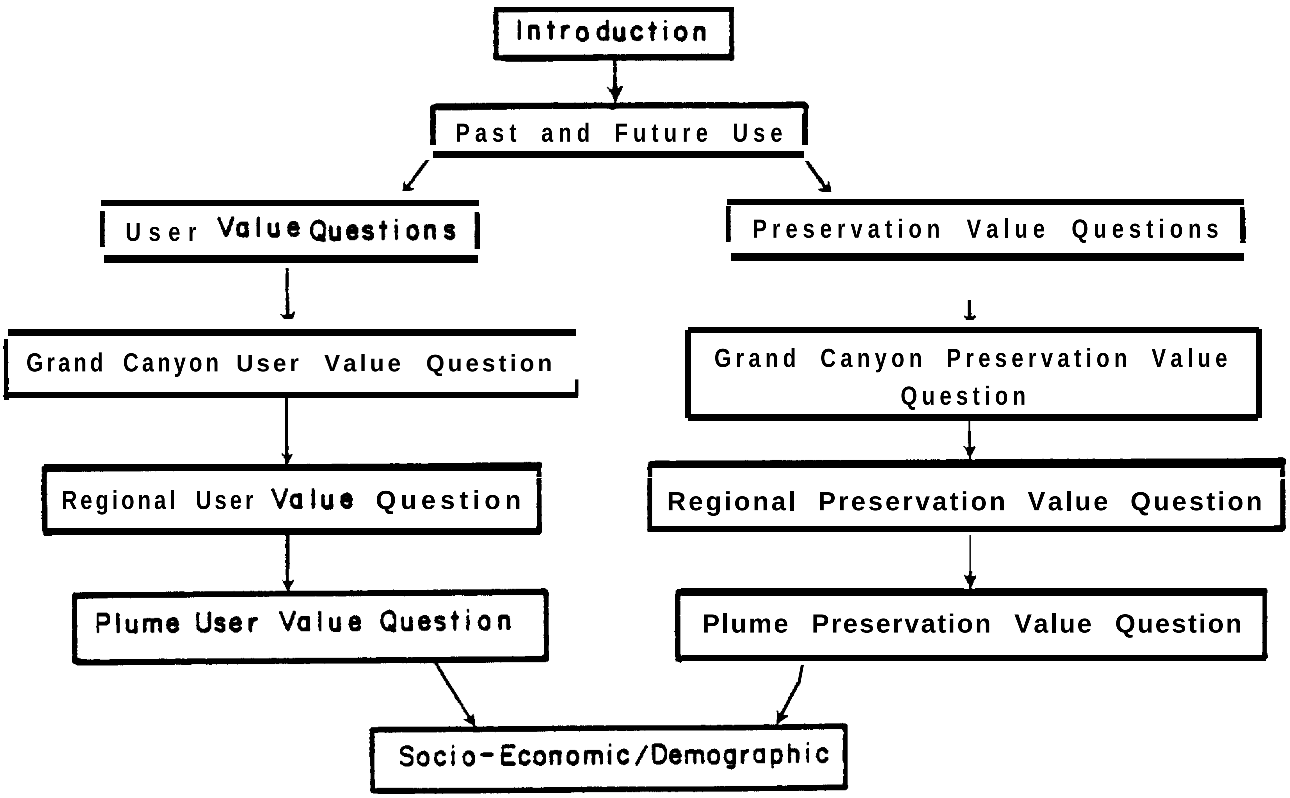
(7,178 ft.) Shiprock, NM - 35 miles from Mesa Verde

(8,029 ft.) Trumbull Mountain, AZ - 50 miles from Zion and 1 mile from Grand Canyon

4

Figure 13

QUESTIONNAIRE STRUCTURE



determined. Households were asked how many days in the last ten years they visited and how many days in the next ten Years they anticipate visiting the above listed National Parks. Two-thirds of the respondents were given the preservation value questions (i.e., user plus existence values), while one-third were given the user value sequence of questions. Every respondent was asked at the conclusion of the valuation questions a set of demographic/economic questions: home zip code, education, age group, sex, size of household, whether the respondent was primary income earner and income group.

The photograph sets utilized were presented to the respondents in a folding display. All respondents were shown identical displays but the valuation process was divided between user and preservation questions. In explaining the photographs the following types of information were given to the respondent:

> The Grand Canyon picture set displays a total of five levels of visibility represented by Columns A through E and three vistas from Hopi Point represented in the rows. Column A represents poor visibility, B below average, C average visibility, D above average and E good visibility. The rows in the picture display represent morning and afternoon views from Hopi Point in the Grand Canyon. The first row represents the different visibility and air quality conditions looking east in the morning from Hopi Point. The second row represents morning conditions looking west from Hopi Point. The third row represents the view from Hopi Point in the afternoon looking west.

> The regional picture set display represents five different levels of air quality from poor visibility, Column A, to good visibility, Column E. The rows represent morning conditions for the Grand 'Canyon, Mesa Verde and Zion National Parks. Row 1 looks out from Hopi Point towards the east in the morning at the Grand Canyon. Row 2 represents the vista from Mesa Verde at Far View Overlook towards the south in the morning. Finally, Row 3 is at Lava Point in Zion National Park looking southeast in the morning.

The Grand Canyon and regional picture set displays were utilized for user and preservation value questions.

> The plume analysis picture display represents two situations. In Picture A no plume can be seen looking west from Hopi Point in the Grand Canyon. Picture B is identical except that a plume is visible.

Again both user and preservation value respondents utilized the same plume picture display.

Three other general characteristies of the questionnaire are worth mentioning. First, after all user and preservation value Grand Canyon and regional bids were obtained, the respondent, if having bid zero, was asked the reason: 1) the air quality improvements represented in the columns were not significant, 2) the source of air pollution should be required to pay the costs of improving the air quality and 3) other (specify). Second, if the respondent stated confusion as to the sources and causes of air pollution or to the veracity of the photographs, a special verbal explanation was given to the respondent explaining the sources and causes of air pollution in more technical detail. This is presented as a supplement to the questionnaire in Appendix B. It was noted on the respondent's questionnaire if this information was requested. Finally, all respondents were shown the map in Figure 12. This was to supplement the picture sets and verbal description in describing the regional nature of the visibility problem.

The areas sampled by the survey teams were chosen in a semi-random fashion in that income class and racial composition were important factors in determining the sampled areas. Approximately one-third of the surveys were to be taken from each of the following income classes; low, medium, and high. Also, it was deemed desirable to obtain an appropriate mix of races representing the average composition across America. Relying primarily on 1970 census tract data it was determined that several areas satisfied the income and race considerations. Thus the actual areas sampled were chosen essentially at random. The out-dated nature of the 1970 data made on-site inspection of the selected areas necessary, but we found the redistribution over the last decade *to* be minimal. Tables 10, 11 and 12 describe in detail the areas sampled and provide some relevant census tract data. Actual data of the sampled population is given elsewhere.

Before the interviewing commenced, a pre-test of the questionnaire was carried out in Laramie, Wyoming. This served to identify problems in the questionnaire and train the interviewing teams. Due to the size of the picture displays and possible reluctance of some respondents to be interviewed by males, male - female teams administered the surveys.

In any interviewing procedure, care must be taken that the process of sampling and interviewing does not introduce biases into the responses. Thus log sheets were kept by each interviewing team detailing whether a household contacted was: 1) not at home, 2) wished to be interviewed later or 3) refused to be interviewed. This allows the final survey results to be checked for non-respondent bias and a type of sampling bias.

Let us turn now to a more detailed look at the content and sequence of user and preservation value questions focusing on specific information given the respondent and the mechanisms utilized for eliciting a response.

C. User Value Questions

The user value questions asked respondents' willingness to pay to improve visibility in the Grand Canyon, willingness to pay to prevent a deterioration of visibility from the current average for the Southwest region and willingness to pay to prevent plume blight over the Grand Canyon.

The payment vehicle for the Grand Canyon user analysis was increments in additional daily entrance fees. Respondents were told that all visitors would end up paying the same total daily fee and further that all monies collected would be used to finance the air quality improvements represented in the

Table 10

Description of the areas sampled for the National Park Survey Los Angeles County

Name of community or area	Boundaries of the area sampled	Census tract number[a]	Mean income[b]	Percent Black[c]	Percent other races[d]
Santa Monica	West: Lincoln Blvd. North: Pico Blvd. South: Ashland East: 20th Street	7022	11,924	1.6	5.2
Venice District	West: Washington Blvd. North: Rose Ave. South: Brooks Ave. East: 6th Ave.	2733	7913	38.9	2.1
Venice District	West: Main Street North: California Ave. South: Venice Blvd. East: Lincoln Blvd.	2736	9864	2.2	3.0
Inglewood	West: Rosewood Ave. North: Arborvitae St. South: Century Blvd. East: La Brea Ave.	6012.02	11,353	.2	2.4
Inglewood	West: Wooster Ave. North: Slauson Ave. South: 62nd Street East: Charlton Ave.	7030	25,876	1.1	1.8
San Marino	West: Los Rabies Ave. North: Monterey Road South: Huntington Dr. East: Oak Knoll Ave.	4641	34,992	.2	.6
Monrovia	West: Myrtle Ave. North: Greystone Ave. South: Lima Ave. East: Shamrock Ave.	4303	13,513	.2	.7

a. As defined in the maps of Block Statistics: Los Angeles - Long Beach, California, Urbanized Area: 1970 Census of Housing, U.S. Department of Commerce Bureau of the Census Publication HC(3)-18.

b. From Table P-4 "Income Characteristics of the Population: 1970" in Census Tracts: Los Angeles Long Beach, California Standard Metropolitan Statistical Area: 1970 Census of Population and Housing, U.S. Department of Commerce Publication PHC(1)-117.

c. From Table P-1 General Characteristics of the Population: 1970, ibid.

d. Calculated from Table P-1, ibid.

Table 11

Description of the areas sampled for the National Park Survey: Albuquerque Metropolitan area.

Name of community or area	Boundaries of the area sampled	Census tract number[a]	Mean income[b]	Percent Black[c]	Percent other races[d]
Albuquerque	West: William Street North: Stadium Blvd. South: Woodward Road East: i-25	13	4968	11.2	2.9
Albuquerque	West: Rio Grande River North: Montano Road South: Candelaria Road East: San Isidro St. and Guadalupe T.	31	10,312	.4	2.3
Albuquerque	West: State Hwy. 448 North: Interstate-40 South: Bridge Blvd. East: Coors Blvd., Central Ave., and Rio Grande River	24	7860	3.2	2.4
Albuquerque	West: 8th St. and 5th St. North: interstate-40 South: Lomas Blvd. East: Broadway N.E.	28	5919	7.9	4.7
Albuquerque	West: interstate-25 North: Grand Ave. South: Hazeldive Ave. East: University Blvd.	16	7161	2.0	5.0
Albuquerque	West: Carlisle Blvd. North: Lomas Blvd. South: Zuni Road East: San Pedro Dr.	5	10,833	.3	2.2
Albuquerque	West: Carlisle Blvd. North: Montgomery Blvd. South: Candelaria Road East: Louisiana Blvd.	2.01	12,254	1.1	1.2
Albuquerque	West: San Pedro Or. North: interstate-40 South: Lomas Blvd. East: interstate-40	6.01	15,613	2.1	.7
Albuquerque	West: Eubank Blvd. North: Candelaria Road South: Indian School Road East: Chelwood Park Blvd.	1.02	12,432	1.5	1.2

a. As defined in the maps of Block Statistics: Albuquerque, New Mexico, Urbanized Area: 1970 Census of Housing, U.S. Department of Commerce Bureau of the Census Publication PHC(1)-5.

b. From Table P-4 " Income Characteristics of the Population of 1970" in Census Tracts: Albuquerque, New Mexico Standard Metropolitan Statistical Area: 1970 Census of Population and Housing, U.S. Department of Commerce Publication PHC (I) - 5.

c. From Table P-1 General Characteristics of the Population: 1970, ibid.

d. Calculated from Table P-1, ibid.

Table 12

Description of the areas sampled for the National Park Survey: The Denver Metropolitan area.

Name of community or area	Boundaries of the area sampled	Census tract number[a]	Mean income[b]	Percent Black[c]	Percent other races[d]
Denver	East: York Blvd. South: 23rd Street North: 32nd Street West: Downing Ave.	23	6582	83.1	1.7
Denver	East: Platte River South: 19th Street North: Speer Blvd. West: Federal Ave.	6	6547	.3	2.7
Denver	East: (I-25) Valley South: Hampden North: Yale West: Colorado Blvd.	40.03	12,365	.3	.7
Denver	East: Colorado Blvd. South: Mississippi Blvd. North: Alameda Blvd. West: University Blvd.	39.01	25,892	.1	.4

a. As defined in the maps of, Census Tracts Denver, Colorado Standard Metropolitan Statistical Area: 1970 Census of Population and Housing, U.S. Department of Commerce Bureau of the Census Publication PHC(1)-56.

b. From Table P-4 "Income Characteristics of the Population: 1970," ibid.

c. From Table P-1 "General Characteristics of the Population: 1970," ibid.

d. Calculated from Table P-1, ibid.

pictures. After explaining the air quality problem in the Southwest region (verbally and via pictures), the payment vehicle, and stating the mean payment criteria, the respondent was asked to bid always comparing the proposed improved air quality (i.e., Columns B or C or D or E) with the lowest air quality conditions as represented in Column A on the picture display. Further, the respondent was asked to assume, when bidding, that each photograph represented the visibility on a day that he would be visiting the Grand Canyon National Park. An example portion of the question presented to the respondent is:

> This is Column A, representing very poor air quality and visibility. Please indicate on your answer sheet how much of an increase above the total daily park fees of $2.00 per car load you would be willing to pay for your household to improve the visibility to that shown in Column B. Put a B next to the highest dollar amount you would pay per day if you were visiting in question E5 on your answer sheet.

While the bidding for Column B versus Column A was being conducted, all other columns were covered up. The process continued for Column A versus Column C etc., again the remaining unused columns were covered.

The regional user value questions varied only slightly from that of the user value questions for the Grand Canyon. First, the picture set was described earlier; second, entrance fees would be raised not just in the Grand Canyon but throughout the national parklands in the Southwest. Finally, the following additional information was provided:

> If current emission standards are maintained, the average conditions will be as seen in Column C. If, however, current emission standards on existing and proposed industrial facilities are relaxed or not enforced, then average air quality and visibility in the region will be represented as in Column B. As shown in Column B a deterioration in visibility would occur in the Grand Canyon, Zion and Mesa Verde National Parks. As a result, conditions as presented in Columns C, D, and E will occur less frequently. Conditions in Columns A and B would occur more frequently. We would like to know how much the maintenance of average regional air quality and visibility is worth to you.

The bidding question presented to the respondents was then for preventing a deterioration from the conditions represented in Column C to conditions in Column B and thus shifting the frequency of occurence of all conditions to a generally poorer level of visibility in the region. The valuation question was as follows:

> How much would you be willing to pay per day in addition to existing park entrance fees for your household at the Grand Canyon, Mesa Verde, or Zion National Parks to prevent a deterioration in visibility in the region as represented

in moving from Column C to Column B. [SHOW photographs AND POINT TO COLUMNS C AND B FOR GRAND CANYON, MESA VERDE AND ZION]. Assume that entrance fees would be raised throughout the National Parks in the Southwest. Please put an R next to the dollar amount closest to the highest increase in daily entrance fees you would be willing to pay for your household for a region-wide preservation in visibility for question E6.

. . .

Finally, the plume analysis addressed visibility problems other than regional haze. The pictures utilized were discussed earlier. Again the bid was in terms of daily entrance fees for the prevention of plume blight while visiting the Grand Canyon.

D. Preservation Value Analysis

The preservation value analysis varied only slightly from the user analysis. First, the vehicle was an increase in monthly electric utility bills. As in the user regional analysis the focus was on the possibility of a shift in the frequency of occurrence of the various visibility conditions represented by Columns A through E. In particular the following information set the background for the bid:

Again, let us look at the photographs representing visual air quality ranging from very poor in Column A to very good in Column E for east and west views in the morning and afternoon from Hopi Point. If current emission standards are maintained the average conditions will be as seen in Column C. If, however, the current emission standards for sulfur oxide are not enforced, then average air quality and visibility in the region will become like Column B. As a result, conditions as represented in Columns C, D and E will occur less frequently. Conditions in Columns A and B would occur more frequently in the Grand Canyon. Such emission controls will likely make electricity more expensive.

The specific bidding question given to the respondents was as follows:

We would like to know if you would be willing to pay higher electric utility bills if the extra money collected would be used for additional air pollution controls to preserve cu-rrent air quality and visibility levels at the Grand Canyon. How much extra would you be willing to pay at most, per month as an increase in your electric utility bill to preserve current average visibility as represented in Column C rather than have the average deteriorate to that shown in Column B? Please put an X next to the highest amount you would be willing to pay per month for your household on your answer sheet for question E8.

The regional preservation value question also used electric utility bills as the bidding vehicle, focused on a shift in the frequency of occurrence from the current average in Column C to that in Column B and utilized the regional picture set board discussed earlier.

A difference, however, between the structure of the regional user and preservation value questions does exist. Recall that the regional user question was a separate bid from that for preserving visibility just in the Grand Canyon. The preservation regional question was a willingness to pay question that asked how much more above and beyond the amount the respondent stated when only bidding for visibility in the Grand Canyon.

Finally, the preservation value plume blight question mirrored that of the user question except that the vehicle was increases in electric utility bills. Again, this was for preserving, thus preventing plume blight over the Grand Canyon.